GIS and Mapping

Pitfalls for Planners

Robert B. Kent and Richard E. Klosterman

The widespread availability of geographic information systems (GIS) and computer mapping software allows individuals with little or no cartographic knowledge and experience to prepare maps for planning purposes. While these maps are often satisfactory, they may not fully serve their intended purposes. This article identifies some of the most common mistakes that planners make in preparing maps and suggests ways to avoid them. It introduces some key considerations in map making and offers a series of practical tips that will help planners produce more effective maps.

Kent is a professor in the Department of Geography and Planning at the University of Akron. His research interests include cartography, regional planning, and the human geography of Latin America. He has worked as an urban and regional planner in Peru and Bolivia. **Klosterman** is a professor in the Department of Geography and Planning at the University of Akron. He edited the *Journal*'s Computer Reports series from 1986 to 1998. His research interests include computer applications in planning, planning methods, and planning theory.

Journal of the American Planning Association, Vol. 66, No. 2, Spring 2000. © American Planning Association, Chicago, IL.

Planners have always depended on maps as essential tools for analyzing current conditions, preparing plans and proposals, and presenting their ideas to others. The widespread availability of geographic information systems (GIS) and computer mapping software in planning offices has made maps even more prominent by making it much easier for planners to produce professional looking maps. However, the greater ease with which maps can be produced has meant that individuals with little or no cartographic knowledge are routinely producing maps for planning purposes. While the results of these efforts are often satisfactory, the maps which are produced may not fully serve their intended purposes (Jones & Kent, 1993; McClendon, 1988; Smith & Kent, 1999; Stringer & Taylor, 1972).

Given the diversity of planners' roles and areas of expertise, it is hardly surprising that few are cartographic experts. Nevertheless, planners could be much more effective in communicating their ideas to others if they avoided a small number of common map-making pitfalls. This article identifies some of these mistakes and suggests ways to avoid them. It introduces some key considerations in map making and offers a series of practical tips that will help planners produce more effective maps.

Failing to Understand the Purpose of the Map

All too often planners use GIS to prepare a map without fully understanding the purpose the map is intended to serve. This results in part from a more fundamental failure to understand that maps can be used to perform three distinct functions, and that a different type of map is required to best carry out each function.

Maps can be used as *reference tools* for storing and conveying geographically-referenced information. Street and road maps, cadastral maps, and topographic maps are all used in this way. They are repositories of information on the location of the features displayed on the map and the spatial relationships between them. Reference maps can be thought of as multidimensional graphical dictionaries or encyclopedias. To be effective, they typically incorporate a wide range of kinds of information about the features they describe. For example, the reference map in Figure 1 shows the counties, county seats, and interstate highways in four counties in northeast Ohio that are referred to locally as the North Coast.

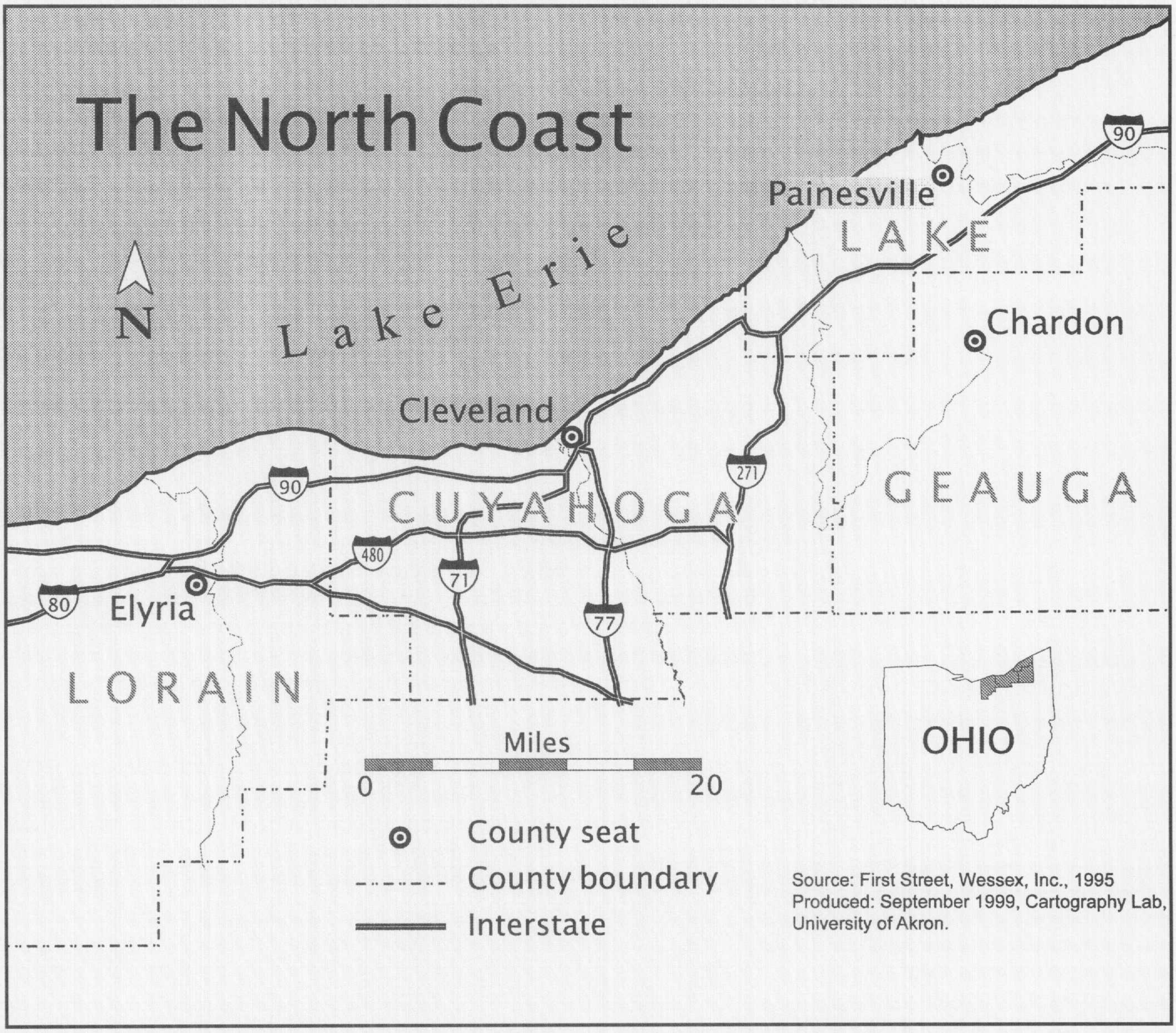

FIGURE 1. Ohio's North Coast.

Maps can also serve as *analytical tools* for uncovering and exploring the spatial dimensions of—and interrelationships between—phenomena and activities located in space. Thus, for instance, maps can be used to examine the relationship between income, race, and education in an urban area or between soil types and different vegetation types in a rural area. Unlike reference maps, maps designed to be used as analytical tools are working documents that are used, for instance, to examine different data sets, explore spatial relationships, and consider the implications of using different class intervals. For example, the analytic maps shown in Figure 2 explore the implications of using different classification schemes to prepare a map showing the number of American Planning Association (APA) members per 100,000 population by state.

Finally, thematic maps can be used as *illustrations* in books, journals, newspapers, planning reports, and public presentations. While reference maps describe the *location* of map features, thematic maps describe the *characteristics* of these features. And while reference maps generally provide many different types of information, a thematic map usually conveys only one or two types of information on the features and locations displayed on the map. Most importantly, thematic maps are designed to convey a message to the viewer. Just as an essay or a newspaper editorial seeks to convince the reader of a particular point of view, thematic maps are created to make a specific point and to persuade the viewer to adopt a particular position. For this reason, the ability of the map maker to design an effective image is critical to a thematic map's success.[1] For example, the top map in Figure 3 shows the relative population of different states and regions of the United States much more clearly than would be possible with a table or chart.

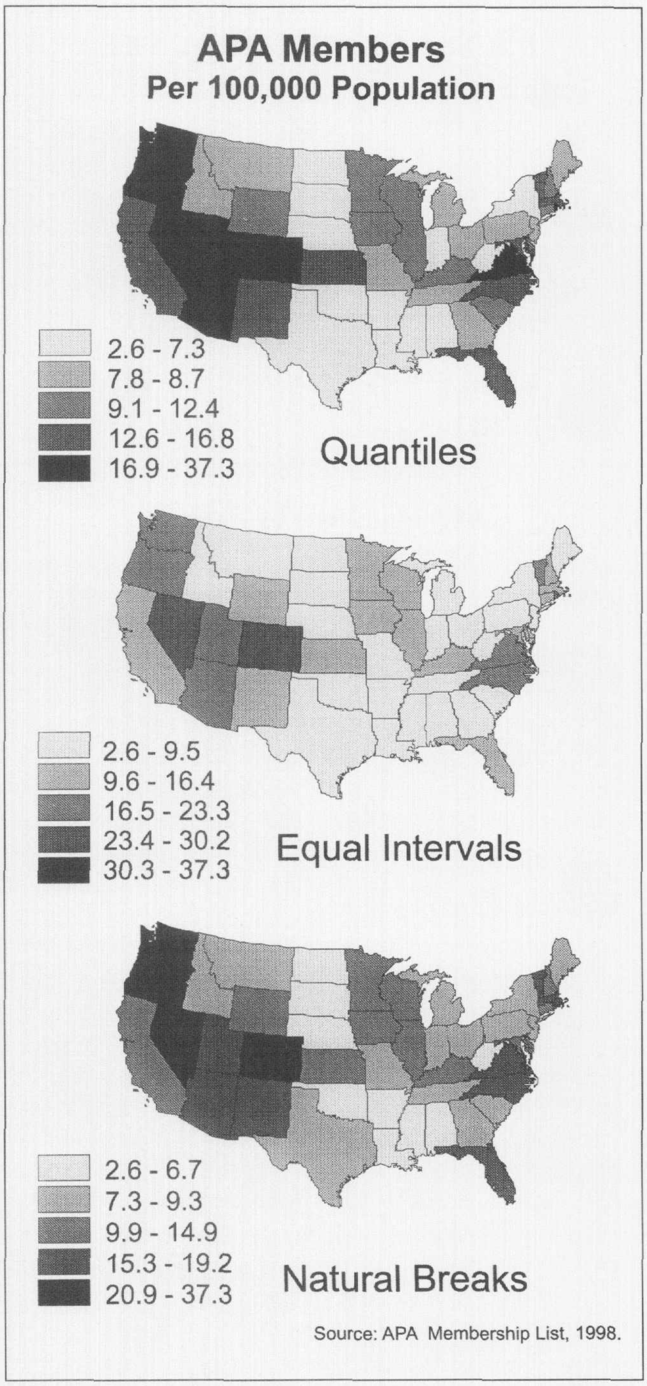

FIGURE 2. Maps of APA membership per 100,000 population by state.

Trying to Improve Accuracy by "Zooming In"

Computer-based GIS and mapping software make it all too easy to take a map that has been prepared at one scale and "zoom in" to look at portions of the map at a larger scale. Thus, for example, a planner may use a small-scale 1:24,000 United States Geological Survey (USGS) quadrangle (quad) sheet for a county to prepare detailed maps showing the location of the roads and buildings in a neighborhood. There is nothing wrong with this. However, it is important to realize that zooming into the map does not make the map more accurate; the only thing that changes is the map scale, i.e., the relationship between the distances shown on the map and distances on the Earth's surface.[2]

To clarify this issue, we must make a distinction between spatial accuracy and spatial precision. *Spatial accuracy* measures how close a recorded location is to its true position on the Earth and is determined by the care used in conducting the initial land survey and establishing the original map scale. *Spatial precision* measures how exactly a location is depicted on a map, regardless of its accuracy. The precision of a map is limited by the width of the smallest line that can be displayed at a given scale.

Thus, for instance, if the finest line on a 1:24,000 quad sheet is 0.5 mm wide, the smallest distance (or "minimum map unit") that can be recorded true to scale is 39 feet. At that scale 1 inch represents 2,000 feet. Zooming in by a factor of 10 changes the scale to 1 inch representing 200 feet, making it theoretically possible to locate features with a precision of 4 feet. However, this precision is misleading, because features cannot be located any more accurately than they were recorded on the original map, i.e., with an accuracy of 39 feet (Robinson et al., 1995).

Neglecting Map Projections and Coordinate Systems

Modern GIS and computer mapping software make it easy not only to prepare a map image but to combine

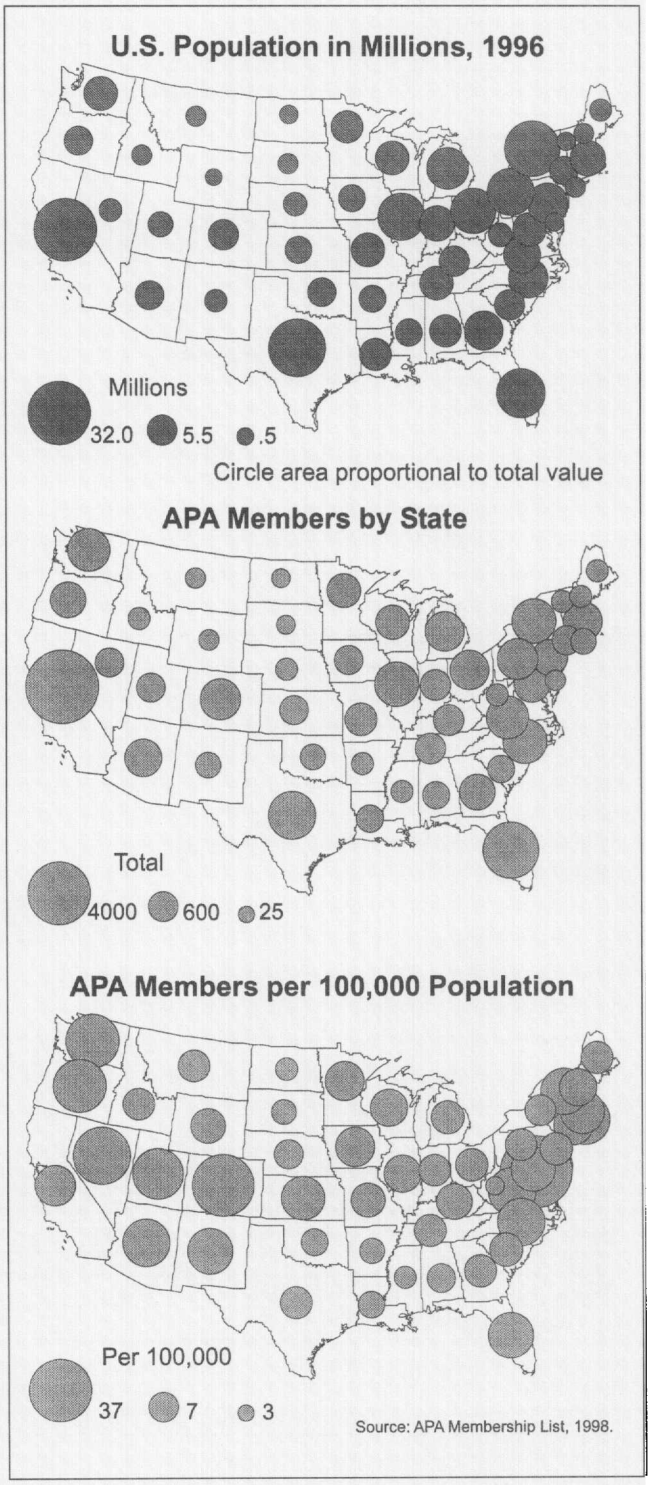

FIGURE 3. Maps of APA membership and population by state.

maps obtained from different sources. In the process, planners often fail to determine the projection, coordinate systems, and "datums" used to prepare the map.[3] The details of map projection, coordinate systems, and datums are of little immediate consequence to most planners. Nevertheless, map projections and coordinate systems can be extremely important because GIS system defaults are often spherical coordinates (e.g., latitude and longitude) that produce distorted images for small areas such as states and counties. In these cases, it is necessary to convert the map coordinates to State Plane Coordinates or another coordinate system that is able to represent small areas more accurately. Map projections and coordinate systems are even more important when planners attempt to combine digital maps that have been produced using different projections and thus may not register correctly. Planners must identify the map projection and coordinate system used to produce any map and know the procedures for using a particular software package to transform them to a common map projection and coordinate system.

Failing to Evaluate and Document Map Sources

Ideally, before preparing a map a planner will always examine a wide range of digital, published, and unpublished maps of the area; select the ones that are most suitable for the purpose; and compile them into the base map.[4] The process of compiling the map's statistical or thematic data should be largely the same as for preparing the base map. That is, the map maker consults existing maps and data sources, assesses their reliability and applicability, selects the most useful and dependable information, and presents it on the completed map.

Unfortunately, the process of map compilation is not always as rigorous as it should be. In the rush to production, the first map found is often assumed to be "good enough," and readily available statistical or thematic data are accepted at face value with little or no critical assessment. The greatly increased access to geographical and statistical databases that are provided with GIS and mapping programs, can be purchased from data vendors, or can be downloaded from the World Wide Web, has contributed to this problem.

However, planners must remember that a map is no better than the spatial and attribute data it contains. They should carefully evaluate the reliability and accuracy of the information they incorporate in their maps. Fortunately, the federal government has established standards requiring that data distributors provide metadata or "data about data" describing the content, quality, source, and other characteristics of their spatial and nonspatial data (U.S. Geological Survey, 1998; Federal Geographic Data Committee, 1999). Planners should become familiar with these efforts, support them, and do their part by preparing metadata for the data they distribute. In addition, they should be sure that the sources for all cartographic and statistical data are clearly identified on their maps.[5]

Not Including Necessary Map Elements

The default options provided by popular GIS and computer mapping packages make it so easy to prepare maps that planners often fail to follow elementary cartographic principles that improve map clarity and communication effectiveness. The most important consideration is that all maps should be able to stand alone —that is, their basic message and purpose should be evident to the map viewer without requiring any supplemental textual information.

To ensure that maps can be understood on their own, they should always contain five basic elements:

- a short, concisely worded title indicating the map's subject, geographical location, and, when appropriate, time frame;
- a legend or key specifying the meaning of all point symbols, line symbols, and/or area fills used on the map;
- a map scale relating distances on the map to distances on the Earth's surface;
- a locational identifier that places the mapped area in its appropriate spatial context (often this is done by including a small inset map that locates the mapped area within a larger, better known geographic entity); and
- a source citation identifying the source for the spatial and thematic data portrayed on the map, the organization that produced the map, and the date on which it was produced.

If the mapped area is not a closed shape, it should also include a border that provides a frame for the map image. The map in Figure 1 illustrates how the use of these map elements provides a complete and easily understood image.

Presenting Too Much Information

It is essential that planners understand that, in most cases, map readers will spend very little time analyzing a map. This means that usually information will be received from the map quickly or not at all. Therefore, it is critical to limit the amount of information presented on a map. Novice map makers have a tendency to overload their maps with detail in an attempt to present a comprehensive picture on a single map. Instead, it is usually best to err on the side of simplicity and produce two or three maps, each focused clearly on a single topic or issue. Different kinds of map information can be stored in different GIS layers to allow the map producer to quickly choose the pertinent information to be displayed on a given map.

Consider, for instance, Figure 4, which shows the four counties of Ohio's North Coast. This map was prepared in the manner of many maps currently being produced. The base image was downloaded from files accessible on the World Wide Web, loaded into a commonly used GIS package, and used to show the interstate highways, rivers, and cities in the four counties. The program's pre-defined options were selected for the map title, north arrow, map scale, and other map features. The result is a serviceable but not particularly attractive or understandable map.

More importantly, this map demonstrates why generalization and classification are crucial for effective map making.[6] The lines depicting the network of streams and rivers provide excessive graphic detail. Furthermore, all of the watercourses are portrayed as equally important, with no effort made to identify major rivers and eliminate streams and creeks. The same problem is evident in the identification of urban centers; no graphic devices or textual information helps the map reader distinguish major urban centers from small towns.

Figure 1 displays the same kind of information for these four counties. However, in this case basic design principles and the application of both generalization and classification have resulted in a more effective map. A gray shade is used for Lake Erie to clearly distinguish it from the land. Instead of showing all the cities and roads, the map shows only the county seats and interstate highways. It also includes a legend, an inset map, and source information and uses a simple bold font for the title and for labeling the map features. These two examples clearly illustrate how attention to design can help planners produce much more understandable and effective maps.

Using Inappropriate Type Faces

Computer mapping programs and GIS programs often present the user with an overwhelming array of type faces. While it may be tempting to select unusual or intricate type faces, they are often difficult to read and may confuse map viewers. Sans serif type faces with simple straight lines such as Univers, Helvetica, and Arial

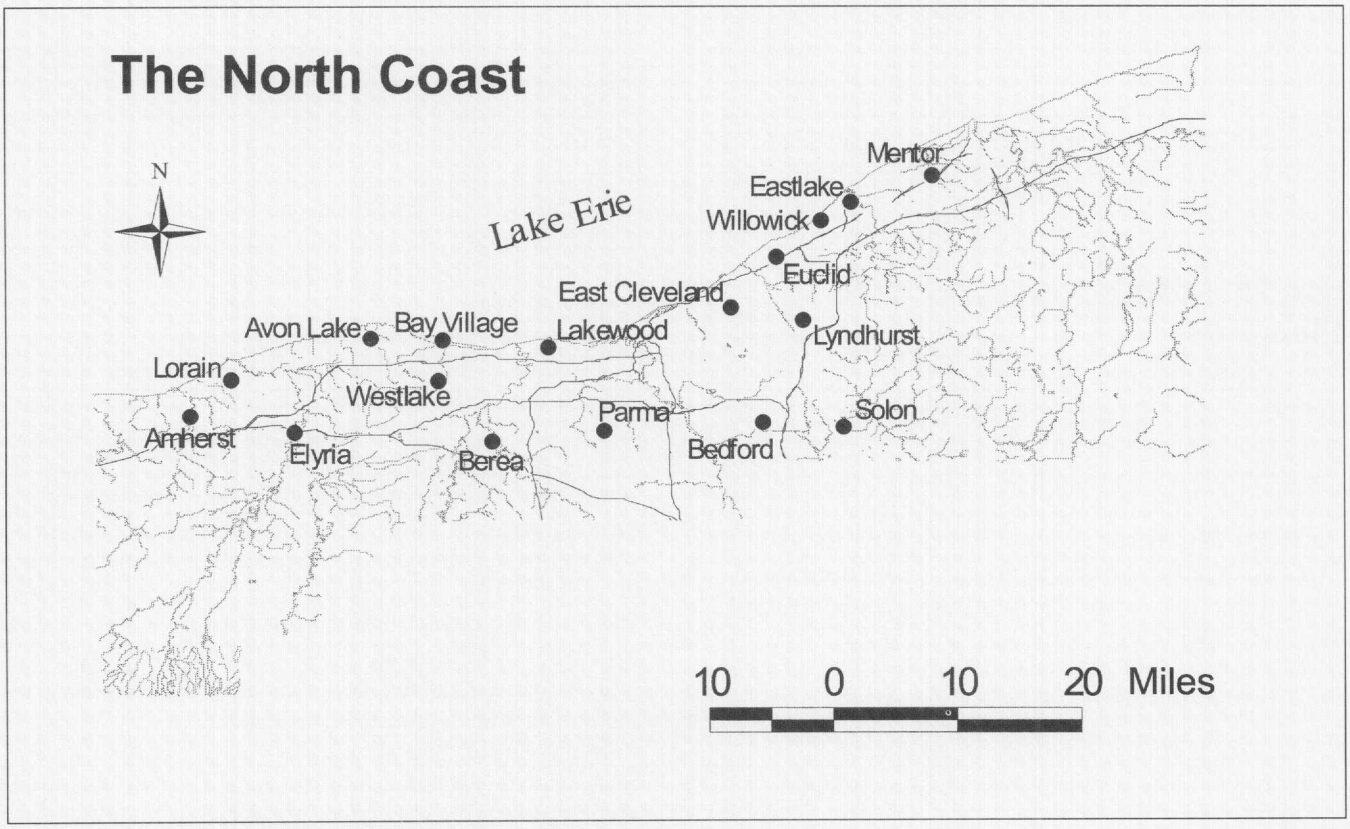

FIGURE 4. Unsatisfactory map of Ohio's North Coast.

are good choices for creating a clear and authoritative look. Serif type faces such as Times New Roman are often preferred when maps accompany text that is set in a serif type face. It is generally best to use the same type family for all lettering on the map or for an entire map series. If desired, distinctions can be created by varying the point size of the type family and using italic or bold type faces.[7]

Standard lettering conventions are used by cartographers to facilitate map reading. These conventions specify that standard lettering (called Roman style) should be used for cities, towns, counties, states, roads, and all other features that are the product of humans. Whenever possible, this lettering should be placed parallel to the top and bottom borders of the map. Natural features such as rivers, lakes, and mountain ranges should be labeled with italic type. The lettering for natural features should follow the course of the feature but should never be placed upside down, as might occur in the case of a sinuous river. Different type sizes and combinations of upper-case and lower-case letters can be used to delineate a hierarchy for places (e.g., state capitals, large cities, smaller cities, and so on). Words with all capital letters should be used sparingly, because they are much harder to read than those with a mixture of upper- and lower-case letters.

When selecting point sizes for map lettering, planners must carefully consider the viewing distance at which the map will be presented to its intended audience. As a general rule, 6 points is the smallest type a map viewer can easily read at the normal distance of roughly 18 inches. As the viewing distance increases, the size of the type must be increased to keep it readable. For instance, lettering must be increased to 80 points to be readable at a distance of 20 feet, and 140 points to be readable at 40 feet. As a result, lettering that is perfectly appropriate for a map published in a planning report is likely to be unreadable if the same map is used in a public presentation (Robinson et al., 1995).

Misrepresenting Qualitative Data

Planners often use abstract or iconic symbols to portray nominal data that describe the characteristics of a place or thing without indicating its size or importance. It is critical that these symbols relay the *qualitative* differences between the features being mapped without implying *quantitative* information about them. For instance, it would be unwise to use triangles of three different sizes to portray schools, churches, and fire stations, since this would imply a functional or hierarchical relationship among them that does not exist. A more suitable solution would be to use different symbols (e.g., a triangle, a square, and a circle) of similar sizes to represent the three features.

Similarly, shades of gray or ranges of color from light to dark should not be used when mapping nominal data describing areas (e.g., different land uses) since the darker tones or colors may be interpreted as being quantitatively more important. If the mapping is done in black and white, then distinctive hatch patterns with little tonal variation should be used. With color, distinct hues (e.g., blue, green, yellow, and red) of equal intensity should be used for different map categories. "Interesting" fill patterns such as bricks and basket weaves should be avoided because they can distract the viewer from the relevant information.

Misrepresenting Quantitative Data

Much of the data planners map are quantitative in nature, reporting absolute numerical values such as population counts, the number of arrests for prostitution, or steel production levels. Planners often map these data by placing scaled symbols whose sizes reflect the value being mapped at point locations or at the centroids of the areas to which the data correspond. In preparing these maps, novice cartographers may be tempted to use pictorial symbols that illustrate the phenomena being mapped (e.g., stick figures for population values) and scale them accordingly. However, pictorial symbols can sometimes be misleading. For example, a stick figure which is twice as tall as another will occupy more than twice as much space, making it unclear just how the two symbols relate to each other. Graduated circles are generally the most effective symbols for communicating with map readers.

Different mapping techniques are needed in preparing *choropleth maps* which portray standardized data values such as population densities, violent crimes per 1,000 population, or mean household incomes.[8] Because these maps report differences in the numerical values of geographic areas, it is important that the shading or patterns reflect the hierarchy. For example, if gray tones are used, then the areas that fall within the lowest class should be represented by white or a light gray, and each subsequent class by a slightly darker gray, with the highest class shown in a very dark gray or black. The maps shown in Figure 2 are examples of this scheme.

Effective graduated color schemes can be constructed several ways, but any scheme should create the impression of increasing density or tonal value. One approach is to use just one color or hue and vary the percentage that is printed for each category, much like a gray scale. Another effective approach is to use a series of hues that starts with a light color for the lower values and uses progressively darker colors to represent larger values. Thus, for instance, a three-color progression could use yellow, orange, and red; a four-color progression might include yellow, green, blue, and violet (McClendon, 1988).

The availability of low-cost color monitors and printers makes it easy to prepare attractive color maps. Unfortunately, color maps are much more expensive to reproduce than black and white ones. As a result, color maps are generally appropriate only for public presentations and for documents that will not be distributed widely. Maps that are submitted for publication or will be duplicated on a copy machine should use gray tone shades or black and white hatch patterns. For instance, an attractive five-category gray tone scale can be prepared by using 0, 25, 50, 75, and 100% fills.

Mapping Absolute Values

Mapping absolute values often obscures important relationships and patterns that are revealed only when the data are standardized against a meaningful common denominator. Assume, for example, that you would like to use a map to help analyze the distribution of the APA membership by state. Your first thought would probably be to prepare a map like the middle one in Figure 3, which shows the total number of APA members in each state. However, compare this map to the top one in Figure 3, which shows the total population for each state. The two maps are practically identical. States which have a large population also have a large number of APA members and states with smaller populations have fewer. This is hardly surprising and the map does little to advance our understanding of the distribution of the APA's membership.

The bottom map in Figure 3, showing the number of APA members per 100,000 people in each state, is much more interesting and informative. It reveals, for instance, that California, New York, and Texas have among the lowest numbers per capita, even though the middle map indicates that they all have many APA members. Conversely, while the middle map indicates that the District of Columbia, Virginia, and North Carolina have relatively small numbers of APA members, the bottom one indicates that they have among the largest numbers per capita. This raises interesting questions about why some states have higher—or lower—concentrations of APA members, irrespective of their total populations.

Neglecting the Effects of Data Classification

Most GIS and computer mapping programs include two to four "standard" data classification techniques. The *quantiles* technique, for example, divides the data into groups with an equal number of observations in each group. For instance, quartiles divide the observations into 4 equally sized classes, quintiles divide them into 5 classes, and deciles divide them into 10 classes. This system has a certain appeal because it divides the data into a predetermined number of classes, achieving a certain numerical balance and sometimes a visual balance on the map. However, the data may not be divided into statistically distinct groups, and the random nature of the numerical divisions often confuses map viewers. The *equal interval* technique divides the data into equally sized large ranges—for example, 0-15, 16-30, 31-45, 46-60, and so on. This technique is appealing because it creates an apparently logical organization of data into groups that are divided at regular intervals. However, since the data values are often distributed unevenly over the range, this technique can generate one or two class intervals that contain the vast majority of the data values while the rest of the class intervals have few or none. Thus, some class intervals may not be represented on the map and others will dominate.

The *optimization* classification technique generally does the best job of retaining the characteristics of the original data set. This technique uses one-way analysis of variance to create data ranges for which the values are as homogenous internally as possible and as distinct from the other groups as possible. The size of the class intervals and the number of observations within the classes generated by this approach are almost always irregular. However, the use of this technique almost always ensures that the class intervals are distinct and statistically and geographically meaningful (Dent, 1996). A similar approach is known as *natural breaks* in which class intervals are established by visually inspecting the data array.

In creating maps, many planners employ these techniques uncritically. However, the application of different classification techniques to the same data will produce maps that communicate very different impressions. For example, the maps in Figure 2 reveal that different classification systems produce remarkably different pictures of the density of APA members. The equal intervals technique places no states in the highest category, only two states—Colorado and Nevada—in the second highest category, and almost half the states in the lowest category; it also displays no clear regional pattern in the number of APA members per 100,000 persons. The quantiles method places an equal number of states in each category and suggests that the density of APA members is generally higher in the western mountain states and on the East Coast than it is in the center of the country. And the natural breaks method puts only four states in the highest category and nine states in the lowest category.

Even more remarkable differences can be noted when we examine the map categories for particular states. The equal intervals method places Virginia in the middle category and California and Florida in the second lowest category. The quantiles method places Virginia in the highest category and California and Florida in the second highest category. And the natural breaks method places Virginia and Florida in the second highest category and California in the middle category. None of the maps is right or wrong; they each provide a different view of the same information. The choice of which to use will depend on the message you want the map to impart to viewers.

Final Considerations

One of the most effective techniques planners can use to test the communicative effectiveness of their maps is to show them to others outside of their offices or areas of professional competence. Ask your colleagues and friends to examine the maps you produce. Can they interpret them? Do they understand the message the map is designed to communicate? Most well designed maps should be comprehensible to educated individuals of average intelligence among the general population. If the maps a planner produces cannot be understood by a nonprofessional, it is time to go back to the drawing board and reconceptualize and/or redesign the map.

Planners must also remember that more is not always better. Having gone to the effort of preparing many maps in the analytic stage of their work, planners are often tempted to include all of them in their final reports, overwhelming the reader. Planners should resist this temptation and include only those maps that are required to support their analysis and recommendations.

An effective map design is essential for accurately communicating spatially referenced information. The guidelines suggested here will help planners avoid many commonly made mapping errors and assist them in preparing maps which communicate their ideas clearly and precisely to a variety of audiences.

ACKNOWLEGEMENTS

The authors gratefully acknowledge the valuable comments and suggestions offered by Claudia James and Joe Stoll of the Department of Geography and Planning at the University of Akron. They also appreciate the comments of the anonymous reviewers, which led to substantial improvements to an earlier version of this article. The maps were prepared by Claudia James.

NOTES

1. Tufte (1983) provides excellent examples of the uses of maps to display information in readily understood ways. Examples of the uses of maps to distort information and confuse readers are provided by Monmonier (1996).
2. Map scale is often expressed as a ratio, the *representative fraction*, between map distances and "real world" distances. Thus, for example, for a representative fraction of 1:24,000, each unit measured on the map represents 24,000 units on the Earth's surface. Measurement units (such as inches or feet) are never used in the representative fraction because it is a ratio and any unit can be used as long as it is the same for both the numerator and denominator.

   It may also be helpful to clarify the sometimes confusing distinction between large-scale and small-scale maps. A *large-scale map* displays a small portion of the Earth's surface, ranging from a parcel or city block to a few square miles. Conversely, a *small-scale map* displays a large area such as an entire city, county, or state. It is important to remember that the two map scales are directly related to the size of their representative fractions and inversely related to the size of the area being mapped. That is, a large-scale map will have a large representative fraction, say 1:1,000 (and cover a small area); a small-scale map will have a small representative fraction, say 1:100,000 (and cover a larger area).
3. *Map projections* are highly complex mathematical algorithms that are used to "project" the irregularly shaped three-dimensional surface of the Earth onto the two-dimensional surface of a paper or electronic map. *Map coordinate systems* such as latitude and longitude, Universal Transverse Mercator (UTM), and the State Plane Coordinate (SPC) are used to identify locations on the Earth's surface precisely with x and y coordinates. *Map datums* such as the North American Datum of 1927 (NAD 27) and the North American Datum of 1983 (NAD 83) are mathematical models for representing the Earth's surface. Excellent introductions to these topics are provided in Committee on Map Projections of the American Cartographic Association (1986, 1988, 1991), Thompson (1988, pp. 238–245), and Robinson et al. (1995, pp. 97–111).
4. The first stage of drawing together the source materials necessary to produce a map is referred to by cartographers as *compilation*.
5. The federal government's digital geospatial metadata standards were developed by the USGS's Federal Geographic Data Committee (FGDC), approved in 1994, and revised in 1998. For detailed information on these standards and their use, see Federal Geographic Data Committee (1998, 1999).
6. It is literally impossible for a map to faithfully portray all of the precise details of the physical or human environment of the area being mapped. As a result, all map making, consciously or unconsciously, involves a process of *generalization*, i.e., selectively representing map features and attributes. *Graphic generalization* modifies the geometric or physical characteristics of the map. Complicated political boundaries, rivers, or coastlines may be smoothed or simplified. Features above a given threshold size may be selected for representation while those below the threshold are eliminated. The size of features such as rivers and roads is generally exaggerated because they would be almost invisible if presented at their actual size. *Thematic generalization* affects the statistical or "attribute" data portrayed on the map. The classification of statistical data into classes is perhaps the most common form of conceptual generalization. However, nominal data on, for example, land uses can also be generalized. For instance, there may be a wide variety of residential land use areas in an urban setting—single-family houses, multifamily units, apartments, and so on. Each of these land use categories could be presented separately as a distinct geographical feature or they could be merged or "generalized" into a single category of "residential" (Kraak & Ormeling, 1996).
7. For excellent advice on the use of type faces and other design elements to produce attractive and understandable maps and graphic displays, see Williams (1994) and Gosney et al. (1990).
8. Choropleth maps typically use political units, census enumeration units, or administrative units as the basic mapping unit. The data are then mapped by classifying the data values into a series of groups or classes and representing those areas whose values fall within the same group with the same hatch pattern, gray tone, or color.

REFERENCES

Committee on Map Projections of the American Cartographic Association. (1986). *Which map is best? Projections for world maps* (Special Publication Number 1). Falls Church, VA: American Congress of Surveying and Mapping.

Committee on Map Projections of the American Cartographic Association. (1988). *Choosing a world map: Attributes, distortions, classes, aspects* (Special Publication Number 2). Falls Church, VA: American Congress of Surveying and Mapping.

Committee on Map Projections of the American Cartographic Association. (1991). *Matching the map projection to the need* (Special Publication Number 3). Falls Church, VA: American Congress of Surveying and Mapping.

Dent, B. D. (1996). *Cartography: Thematic map design* (4th ed.). Dubuque, IA: Wm. C. Brown.

Federal Geographic Data Committee. (1998). *Content standards for digital geospatial metadata*. Reston, VA: Author.

Federal Geographic Data Committee. (1999). FGDC metadata [On-line]. Available: <http://www.fgdc.gov/metadata/metadata.html>.

Gosney, M., Odam, J., & Schmal, J. (1990). *The gray book: Designing in black and white on your computer*. Chapel Hill, NC: Ventana Press.

Jones, G., &. Kent, R. B. (1993). Map use in small-town planning documents in northeast Ohio. *Ohio Journal of Science, 93*(5), 122–125.

Kraak, M. J., & Ormeling, F. J. (1996). *Cartography: Visualization of spatial data.* Essex, UK: Addison Wesley Longman Limited.

McClendon, D. M. (1988). Tips for better maps. *Planning, 54*(8), 14–19.

Monmonier, M. S. (1996). *How to lie with maps.* Chicago: University of Chicago Press.

Robinson, A. H., Morrison, J. L., Muehrcke, P. C., Kimerling, A. J., & Guptill, S. C. (1995). *Elements of cartography* (6th ed.). New York: John Wiley and Sons.

Smith, A. B., & Kent, R. B. (1999). Map use in comprehensive city plans. *Applied Geographic Studies, 3*(1), 1–17.

Stringer, P., & Taylor, M. (1972). Plans as seen by the public. *Built Environment, 1*(6), 121–124.

Thomson, M. M. (1988). *Maps for America: Cartographic products of the U.S. Geological Survey and others*. Washington, DC: U.S. Government Printing Office.

Tufte, E. R. (1983). *The visual display of quantitative information*. Cheshire, CT: Graphics Press.

U.S. Geological Survey. (1998). *The value of metadata: The national spatial data infrastructure*. Reston, VA: Author.

Williams, R. (1994). *The non-designer's design book: Design and typographic principles for the visual novice*. Berkeley, CA: Peachpit Press.